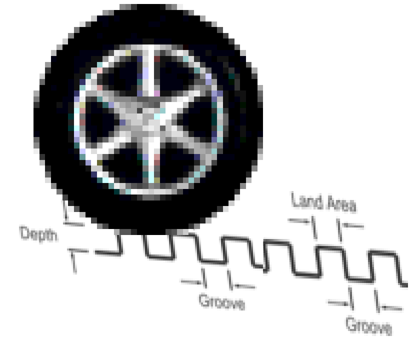
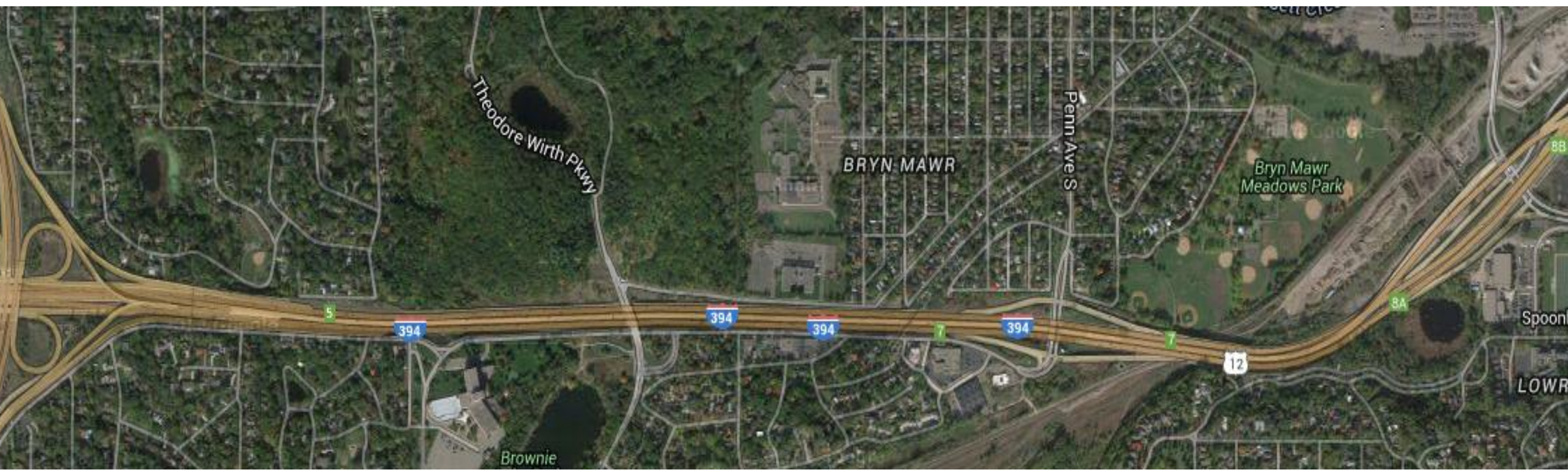
2015 Rehabilitation of Interstate 394 (Bryn Mawr Neighborhood MN) NGCS Research Pays Off



Bernard Igbafen Izevbekhai, P.E. PhD
Research Operations Engineer



MnDOT Office of Materials & Road Research

Research Pays Off Colloquial Series

ARCHAIC PAVEMENT NOISE CHRONOLOGY

8000 BC
Worlds First Major Town-Jericho

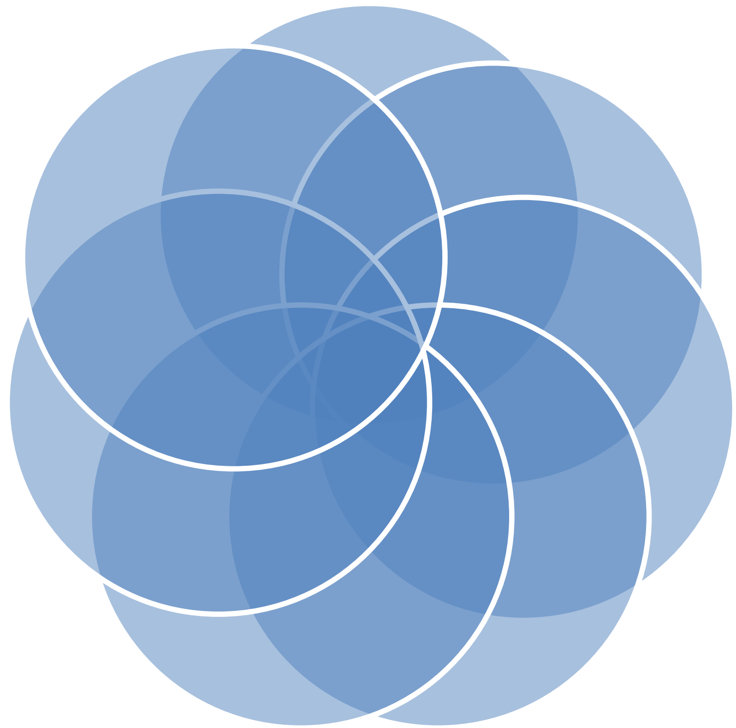
5000 BC
Wheel Invented

4000 BC
Mesopotamia

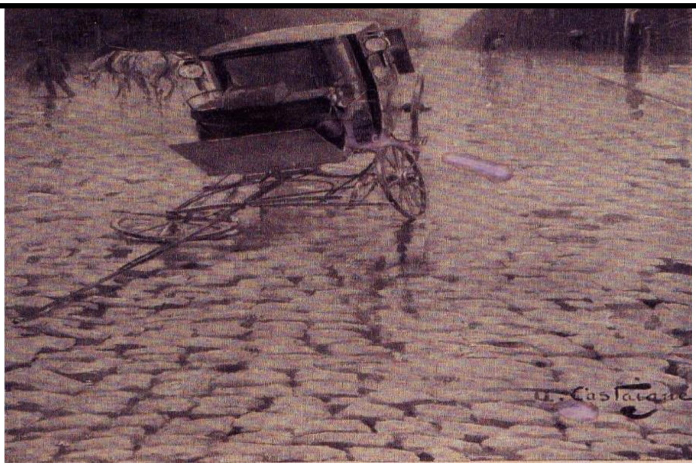
800 BC Iron Tires Introduced

44 BC
First Noise Regulation

1869
London Report

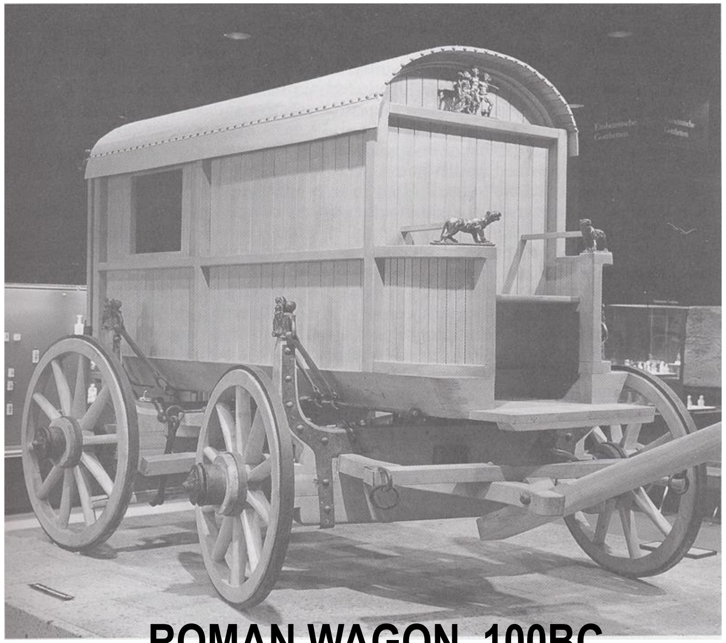


PAVEMENTS WERE DESIGNED TO CARRY TRAFFIC LOADS



Oldest Paving: UR 4000BC

Egyptian Segway 1900 BC (Chariot)



ROMAN WAGON 100BC

US INTERSTATE EDICT 1955 AD

PAVEMENT STRUCTURE VS FUNCTION

Structural Requirements

- Dynamic Stability
- Static Stability
- Global (Overall Stability)

Functional Requirements

- Ride,
- Safety
- Low noise
- Drainability

Functional Requirements Tend to Trigger Rehab and Replacement

TRAFFIC NOISE: THE BANE OF CIVILIZATION

In 170 BC the earliest paved streets were built in Rome. Passable in all weather, but the

disadvantage of increasing traffic noise……

The first documented noise regulation in the world

"no wheeled vehicle whatsoever will be allowed within the precincts of the city, from sunrise until the hour before dusk..."

---Emperor Julius Caeser 44 BC

TRAFFIC NOISE: THE BANE OF CIVILIZATION

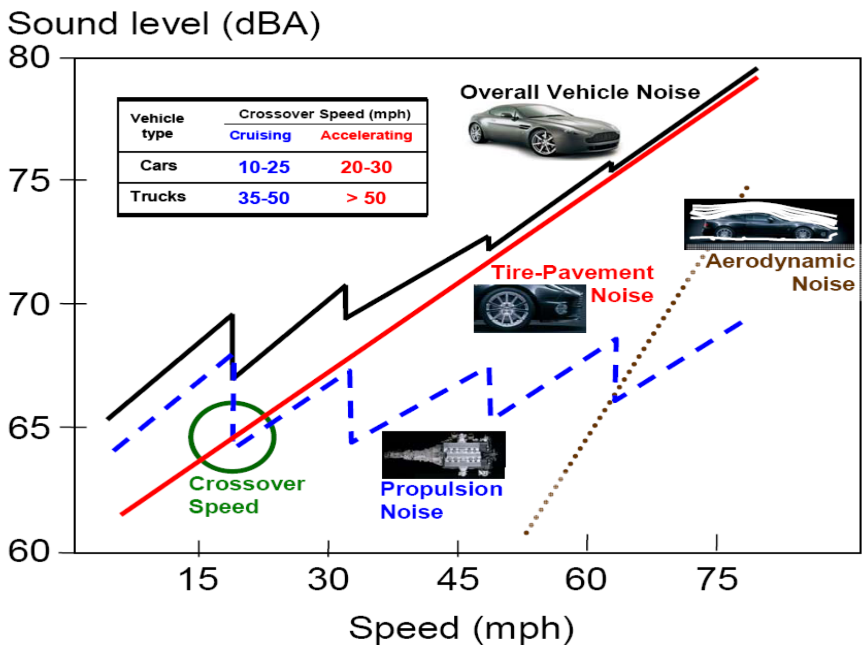
In 1996 After construction of a concrete pavement…A legislative document Mandated a Non-Concrete surfacing…

<u>A documented noise regulation in Minnesota</u>

"1996 Legislative Doc.."

---Legislative Reference :

ACOUSTIC MOTIVATIONS



Rasmussen et al 2007

TPIN IS THE MOST IMPORTANT ROAD NOISE SOURCE

Traffic Noise Raises Stroke Risk

A Web MD Publication, attributes increased risk of stroke to Traffic Noise

http://www.webmd.com/stroke/news/20110124/traffic-noise-raises-stroke-risk?src=RSS_PUBLIC

Noise Abatement Walls Demerits

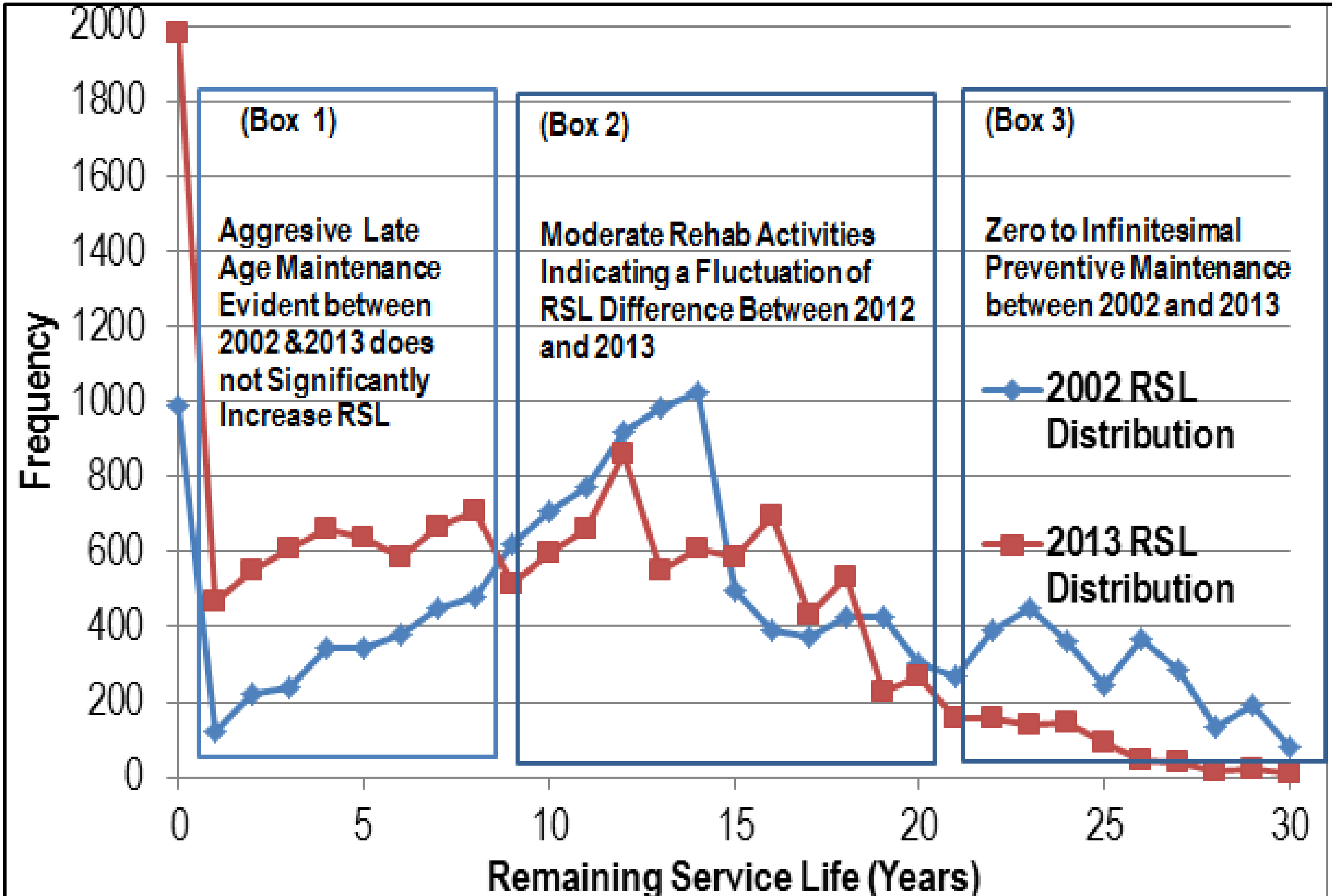
- Thermal Inversion
- Huge Cost
- Reduction of Right of Way
- Drainage Inhibition

Izevbekhai 2012

BRIEF INTERSTATE 394 TIMELINE

- Original construction of Interstate highway 394 was performed in the 1987 SP 2789-48 construction project. SP2789 -18 1990 HOV.
- Transverse tining is associated with noisy tone from tire pavement resonance.
- Subsequently overlaid with an asphalt pavement that lasted for 10 years. In 1996 for noise reduction, the section received a 2 inch bituminous overlay.
- Sequel to this a 1 ¾ inch mill and a 5/8 inch overlay with an ultrathin bonded wearing course was performed in 2004.
- Prior to 2015 a concrete rehabilitation project was designed for this section and discussions were held over the acoustic implication of removing the bonded wearing course and replacing it with a concrete surface.
- 2015 Rehab and NGCS Grinding SP 2789-136

A STRONG CASE FOR REHAB



REPAIRS ON I-394

Anticipated

80% Partial Depth Repairs 20% Full Depth Repairs

Removal of UTBWC

True Condition of Underlying Concrete

20% Partial Depth Repairs

80% Full Depth Repairs

Found Necessary

REMOVAL OF UTBWB

TYPICAL AFTER UTBWC REMOVAL

FULL DEPTH REPAIRS ON I-394

FULL DEPTH REPAIRS

NGCS TIMELINE

Concept To Deployment

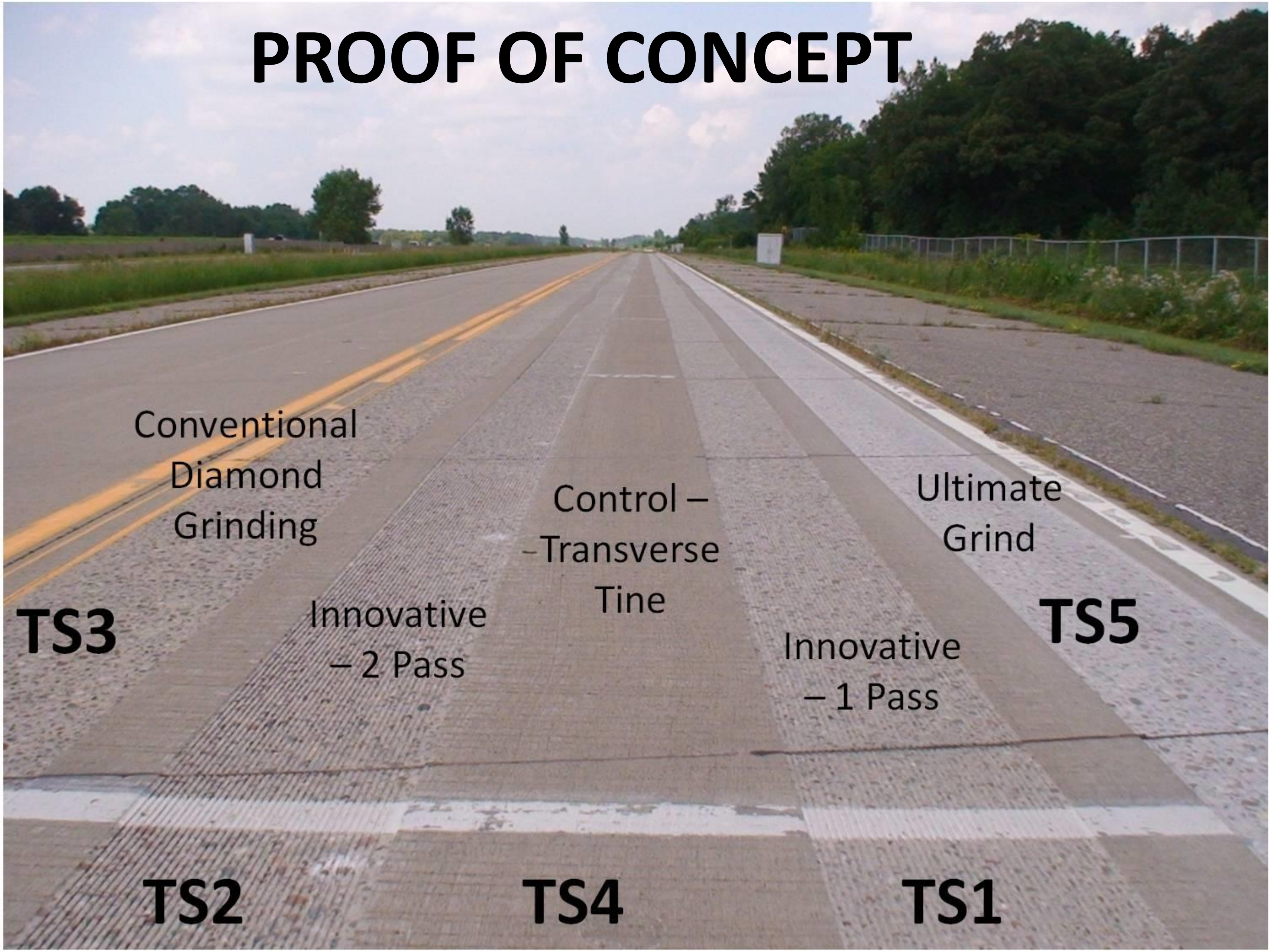
NGCS TIMELINE

❑LAB CONCEPTUALIZATION (2005-2007)

- Purdue Lab Wheel

❑MNROAD FIELD DEMONSTRATION (2007-2010

- Conventional Grind
- Innovative Grind
- Ultimate grind
- 2010 Ultimate Grind


PROOF OF CONCEPT
Conventional
Diamond
Grinding
Control –
–Transverse
Tine
Ultimate
Grind
TS3
Innovative
– 2 Pass
Innovative
– 1 Pass
TS5
TS2
TS4
TS1

Summer 2007 MnROAD Proof of Concept Grind and Evaluation

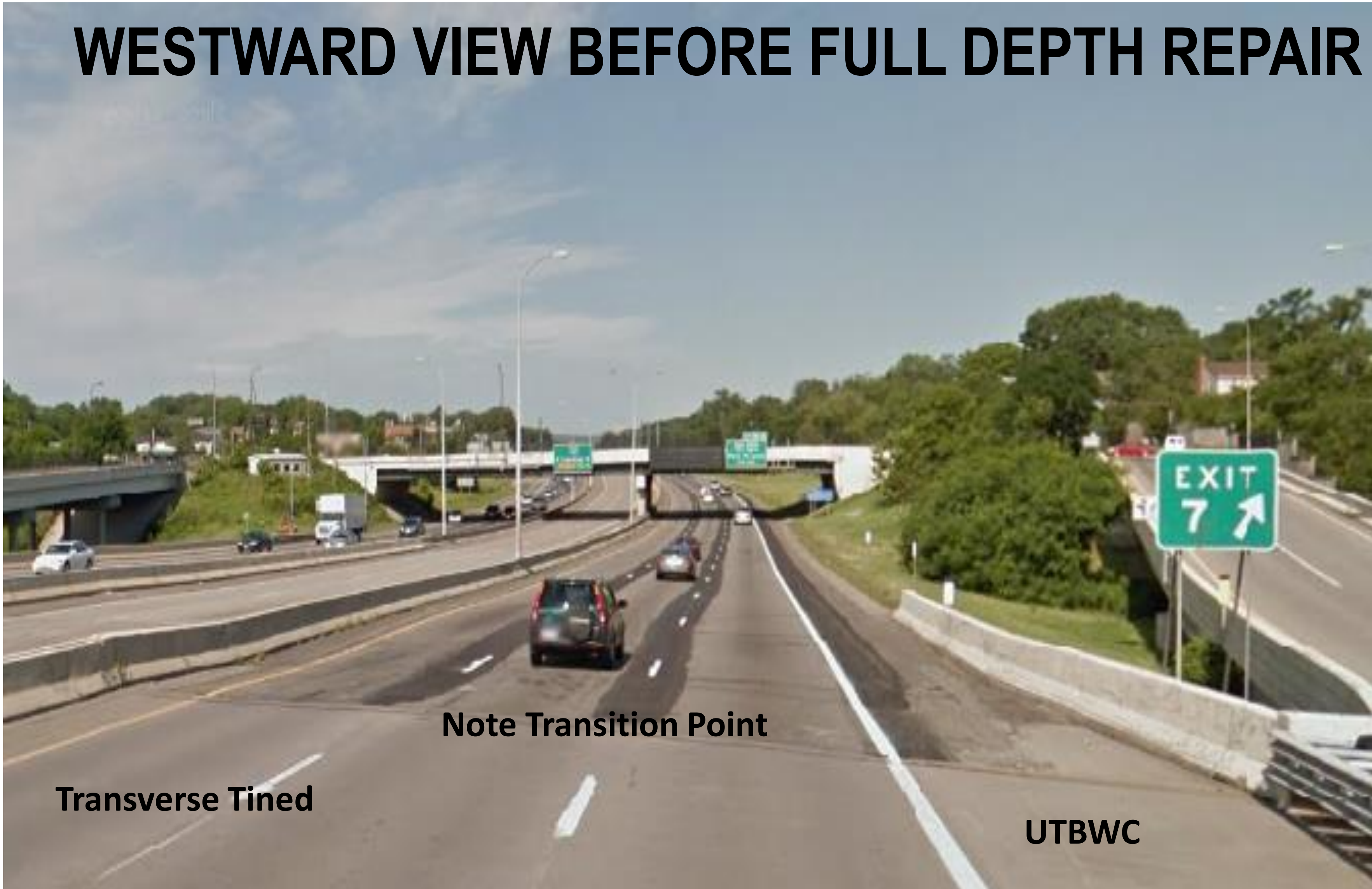
- TS1 was a flush grind and groove in one pass, TS2 was the flush grind and groove in 2 passes,
- TS3 was the conventional grind of .125X .125 X 0.066 inch grove land, depth configuration TS1 and
- TS2 represented the innovative configuration with the difference of the number of passes to achieve each configuration.
- TS4 was the original non-uniform transverse tine that was in the entire lane before grinding.
- TS5 NGCS (2010)

SUMMARY OF CONFIGURATIONS AT MNROAD

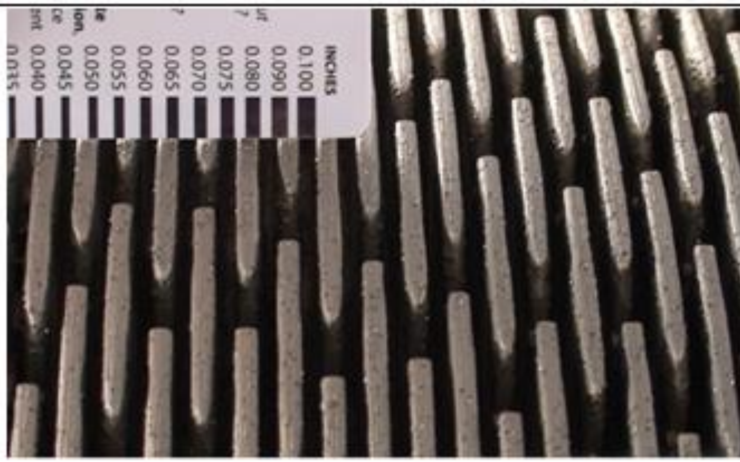
	Cell 9 2008 Innovation		Cell 71 DL NGCS: Corrugations on landing 1/32 " deep and 1/8" Centers		Cell 9 Trans Tining (Before Grinding)		Cell 7 2007 Innovation		Cell 8 Conventional	
	Inch	mm	Inch	mm	Inch	mm	Inch	Mm	Inch	mm
Mean Land Width	0.68	14	0.5	12.7	Transverse tine 0.5 to 1inch (12.7-2.4mm) variable interval 1/8 inch (3.108 mm) deep		0.50	12.7	0.125	3.18
Mean Groove Width	0.31	7.85	0.120	3.048			0.120	3.048	0.125	3.18
Mean Groove Depth	0.18	4.57	0.125	3.175			0.125	3.175	0.125	3.18
Mean Texture E-965	0.06	1.62	0.035	0.9	0.039	1.000	0.035	0.9	0.047	1.2
Mean Texture E-2157	0.06	1.45	0.035	0.88	0.035	0.900	0.035	0.88	0.047	1.2
OBSI (dBA)	101.0		98.7		103.0		98.7		102.7	
Ribbed Friction E-274	53		47		50		47		68	
Smooth Tire Friction	50		49		30		49		48	

DIAMOND GRIND IMPROVEMENTS

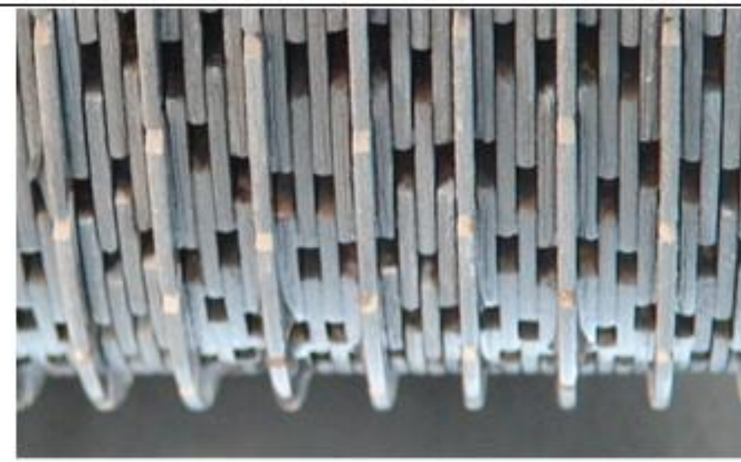
DEPLOYMENT TH 94 MP 185 NEAR MONTICELLO


WESTWARD VIEW BEFORE FULL DEPTH REPAIR
EXIT
7
Note Transition Point
Transverse Tined
UTBWC

DIAMOND GRINDING BLADE STACKING



a)Blade Stacking(Conventional Grind)



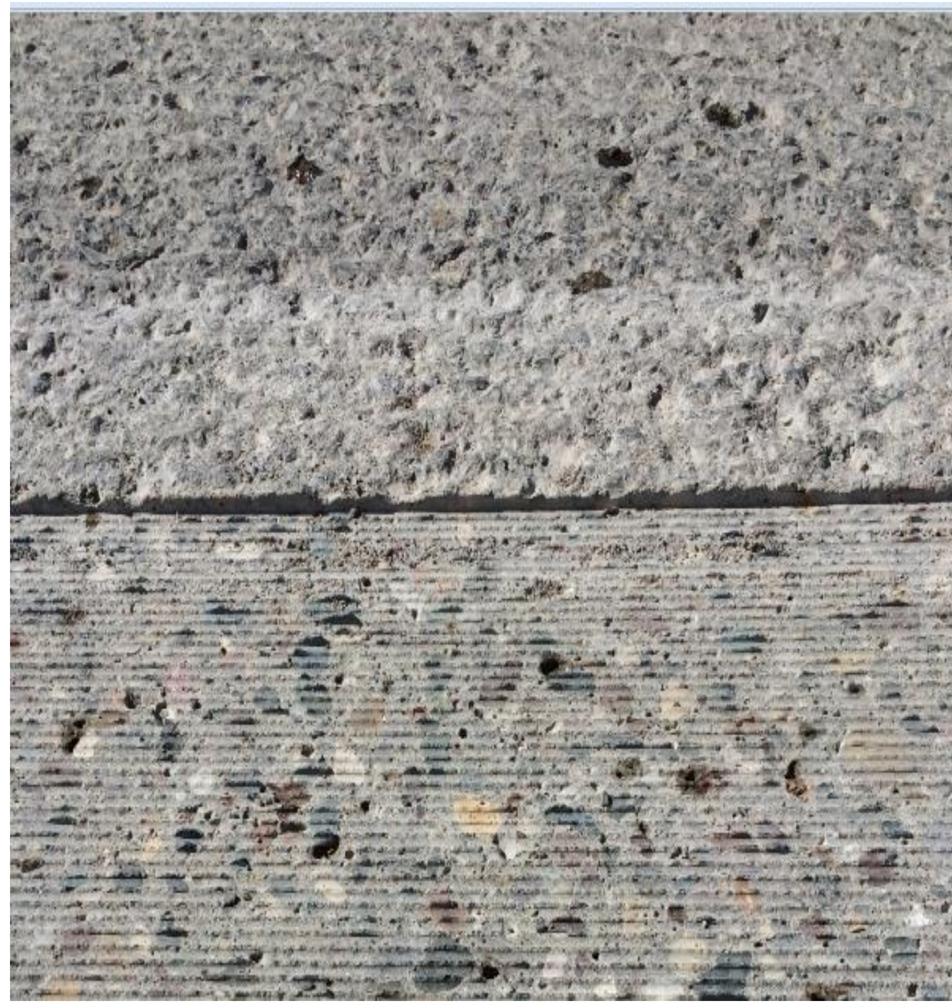
b) Blade Stacking (Innovative Grind)

c) Conventional Grind

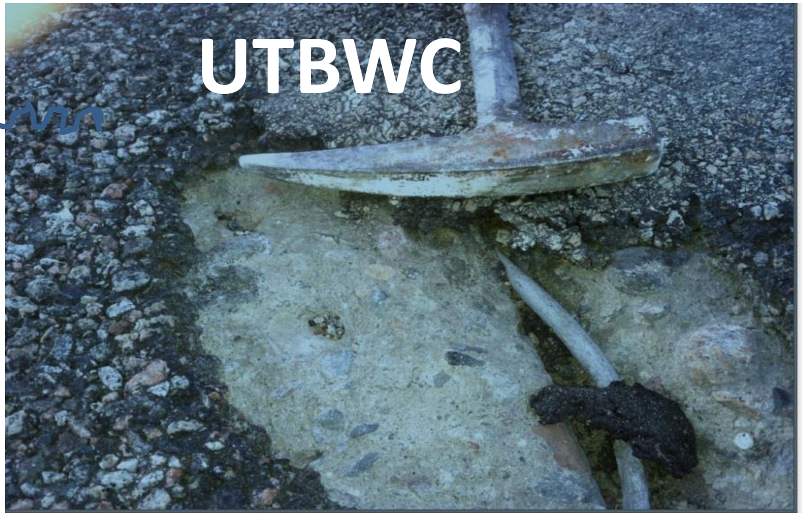
d) Innovative Grind

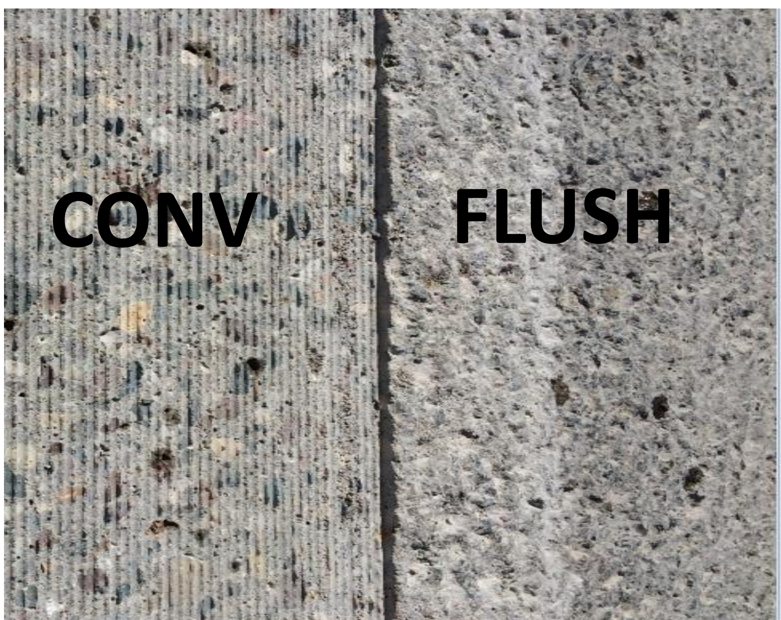
GRINDING STAGES: REVERSED STAGING

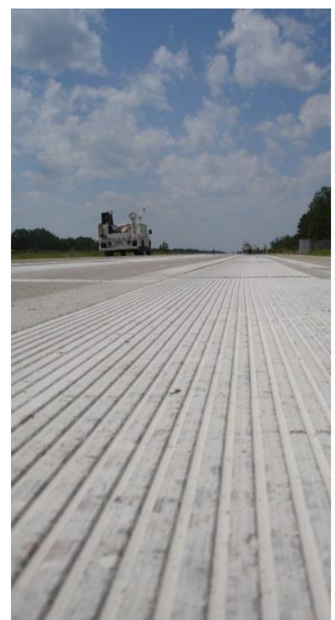
- **Grinding Stages 1**
  Flush Grind
- **Grinding Stage 2**
  Conventional Grind
- **Grinding Stage 3: NGCS**



PROGRESSION: REMOVAL TO REPAIRS TO GRINDING







MEASUREMENT AND ANALYSIS OF OBSI BEFORE & AFTER GRINDING

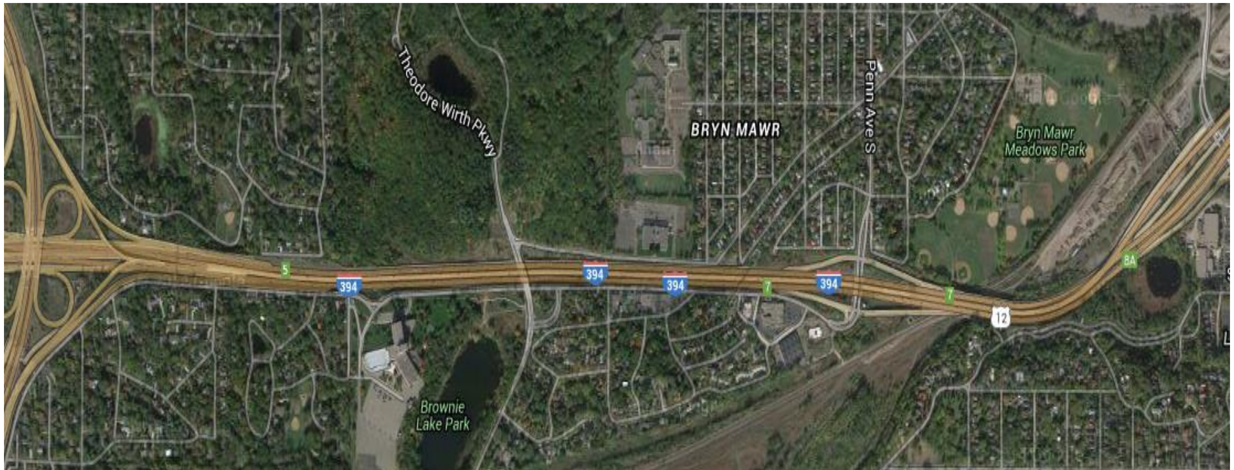
Theory without practice is empty, practice without theory is blind”

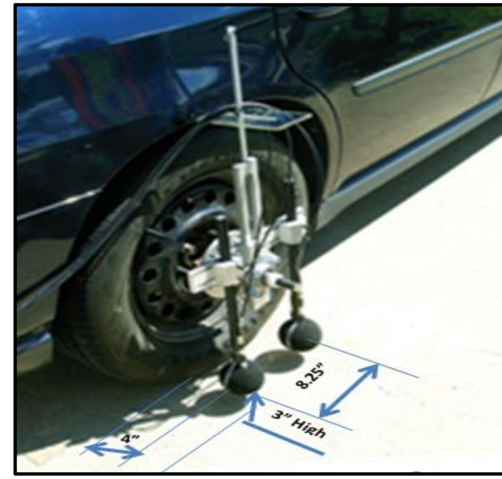
--- German Philosopher Immanuel Kant (1724-1804)

“Theory without practice is for geniuses, practice without theory is for fools and villains, but for most educators (Researchers) [there] is the profound, indissoluble union of both.”

--- Dutch Pedagogue J.H. Gunning (1859-1951)

OBSI TESTING





Segment	Direction	Description of Test Location
1	WB	Between Dunwoody Blvd & Penn Ave
2	WB	Between Dunwoody Blvd & Penn Ave
3	WB	After Penn bridge to entrance ramp gore area
4	WB	After entrance ramp gore area at Penn Ave & Theodore Wirth Pkwy
5	WB	After entrance ramp gore area at Penn Ave & Theodore Wirth Pkwy
6	WB	Between Theodore Wirth Pkwy and TH100
7	WB	Between Theodore Wirth Pkwy and TH100
8	EB	Between TH 100 & Theodore Wirth Pkwy
9	EB	Between TH 100 & Theodore Wirth Pkwy
10	EB	Between Theodore Wirth Pkwy and ramp gore area at Penn Ave
11	EB	Between Theodore Wirth Pkwy and ramp gore area at Penn Ave
12	EB	At Penn Ave "Exit 7" sign to Penn bridge
13	EB	Between Penn Ave & Dunwoody Blvd-Start a chain fence and wood wall trar
14	EB	Between Penn Ave & Dunwoody Blvd

AASHTO TP 76-11

- **Pre Grind April 18: 6-9am Window**
- **Post Grind Oct 25 6-9am Window**
- **3 Loops Per Test**
- **14 Contiguous Sections**
- **Calibration before Each Test**
- **Checked Coherence**

TEMPERATURE CORRECTION

- Δ OBSI$= \mathbf{20.164}\left[\left(\frac{\mathbf{293-T}_{\boldsymbol{b}}}{\mathbf{T}_{\boldsymbol{b}}}\right)-\left(\frac{\mathbf{293-T}_{\boldsymbol{a}}}{\mathbf{T}_{\boldsymbol{a}}}\right)\right]$ (Equation 9)
- Pre-construction OBSI centered at 8 am temperature on April 18 (T_b)
- Post-construction OBSI centered at 7 am temperature on October 25 (T_a)
- Tb = 284.0 ^{o}K
- Ta = 276.9 ^{o}K
- Δ OBSI ≈ 0.7dB

INTERPRETATION OF OBSI DIFFERENCE

If $OBSI_{(1)} - OBSI_{(2)} = n$ where $OBSI_{(1)}$ and $OBSI_{(2)}$ respectively measured sound intensity before and after a pavement surface treatment and "n" is the difference in decibel (dB) then

$$10 \log \left(\frac{SI_2}{SI_0}\right) - 10 \log \left(\frac{SI_1}{SI_0}\right) = n \qquad \text{(Equation 5)}$$

Where SI_1 is the Post-Construction Noise level and SI_2 is the Preconstruction noise level SI_0 is the sound intensity at the threshold of human hearing, (10^{-12} Watts/m^2) then

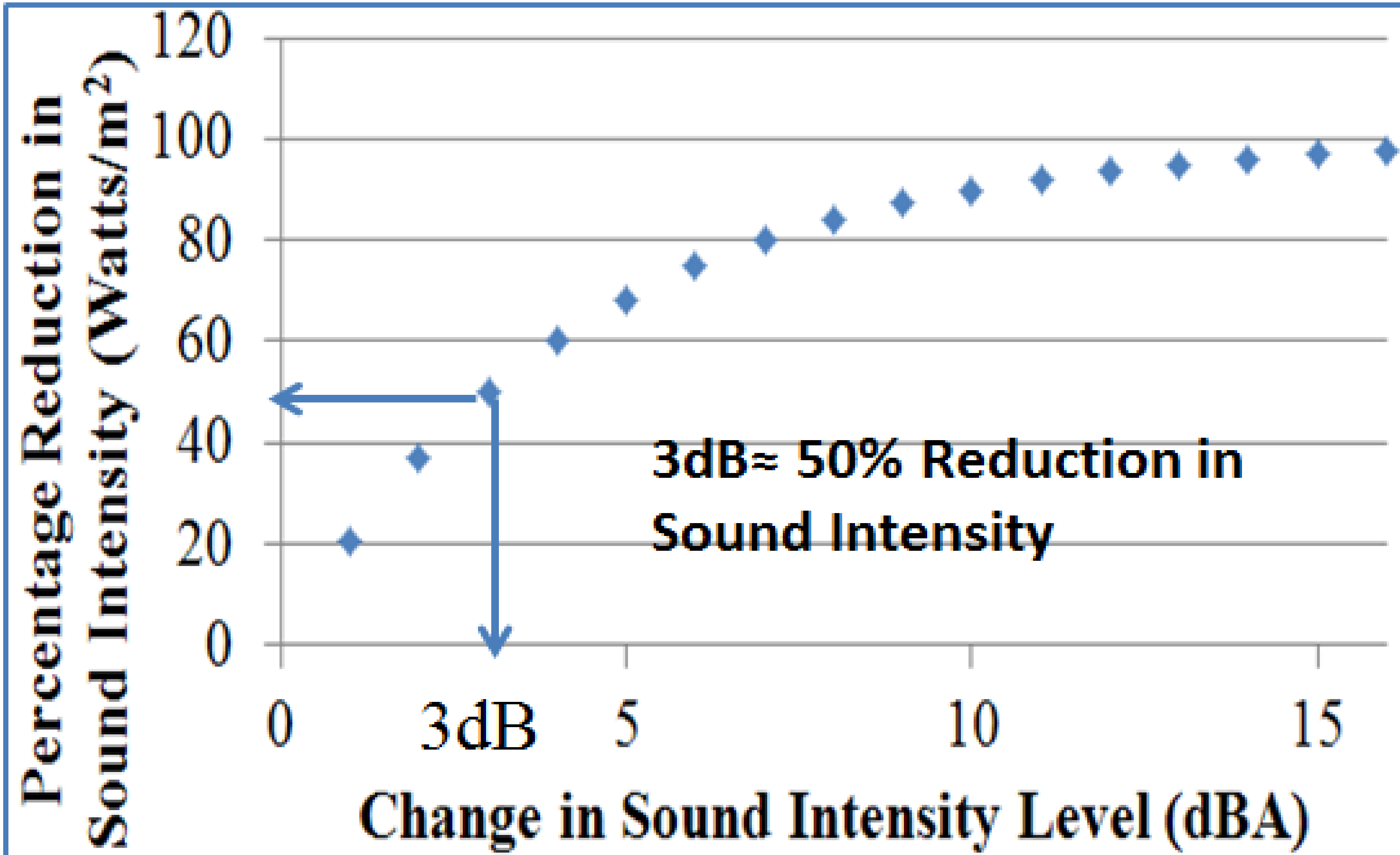
$$\left(\frac{SI_2}{SI_1}\right) = 10^{\frac{n}{10}}. \qquad \text{(Equation 6)}$$

Therefore the actual reduction in sound intensity (Watts/ m^2)

Percentage reduction = $100\left(1 - 10^{-\frac{n}{10}}\right)$.

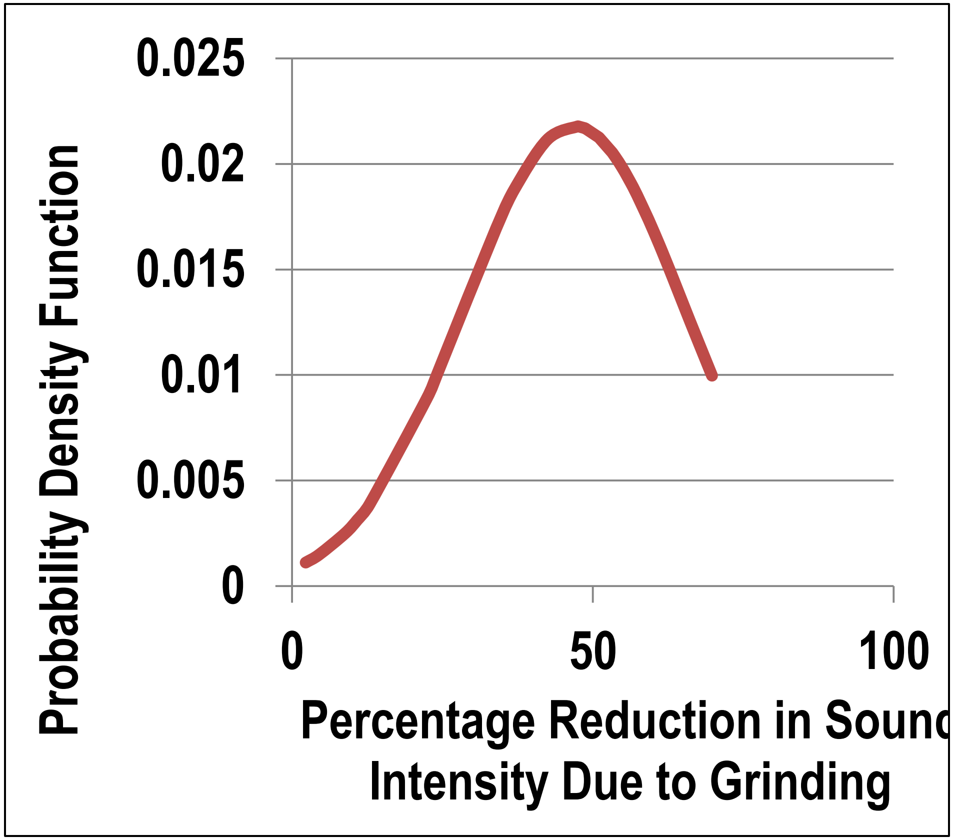
Temp Correction $\cong 0.7\ dB$

IMPLICATION OF OBSI DIFFERENCE

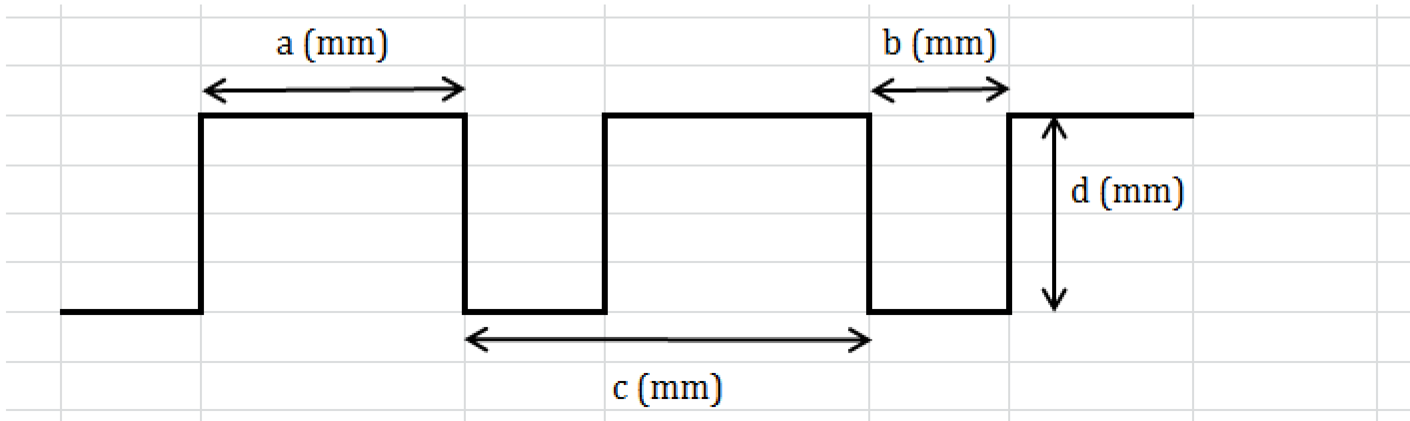


TIRE PAVEMENT NOISE RESULTS

PREVIOUS →	*UTBWC*	*T. TINE*	ALL DATA
Mean	55.68	24.97	46.91
Standard Error	1.55	5.20	2.82
Median	56.80	23.25	53.23
Mode	63.70	48.70	63.69
Standard Deviation	8.47	18.01	18.30
Kurtosis	0.55	-1.27	0.34
Skewness	-0.87	0.39	-1.17
Range	35.90	50.90	67.52
Minimum	33.90	2.30	2.30
Maximum	69.80	53.20	69.80
Count	30.00	12.00	42.00
Largest	69.80	53.20	69.80
Smallest	33.90	2.30	2.30

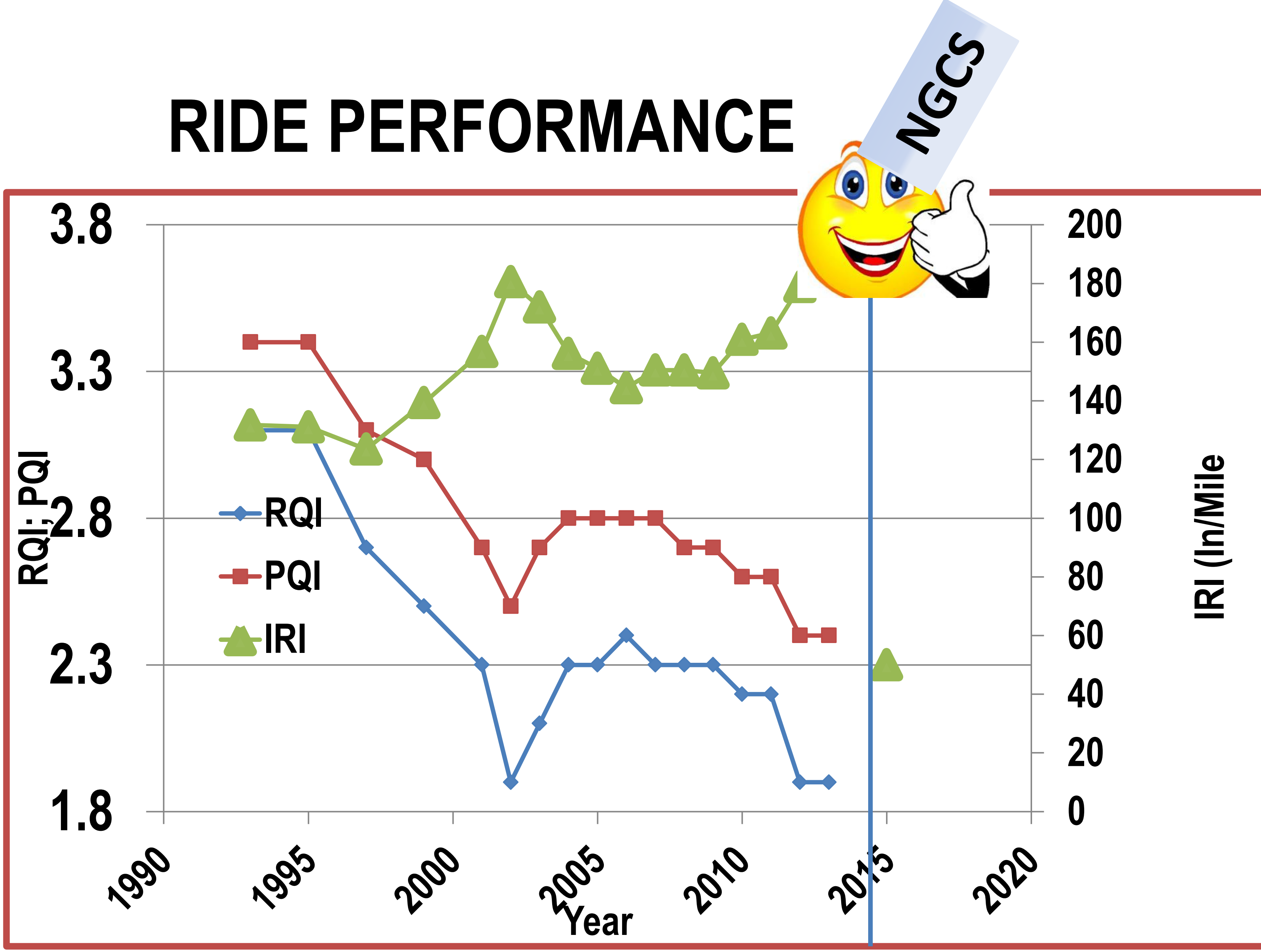


PROBABLE CAUSE

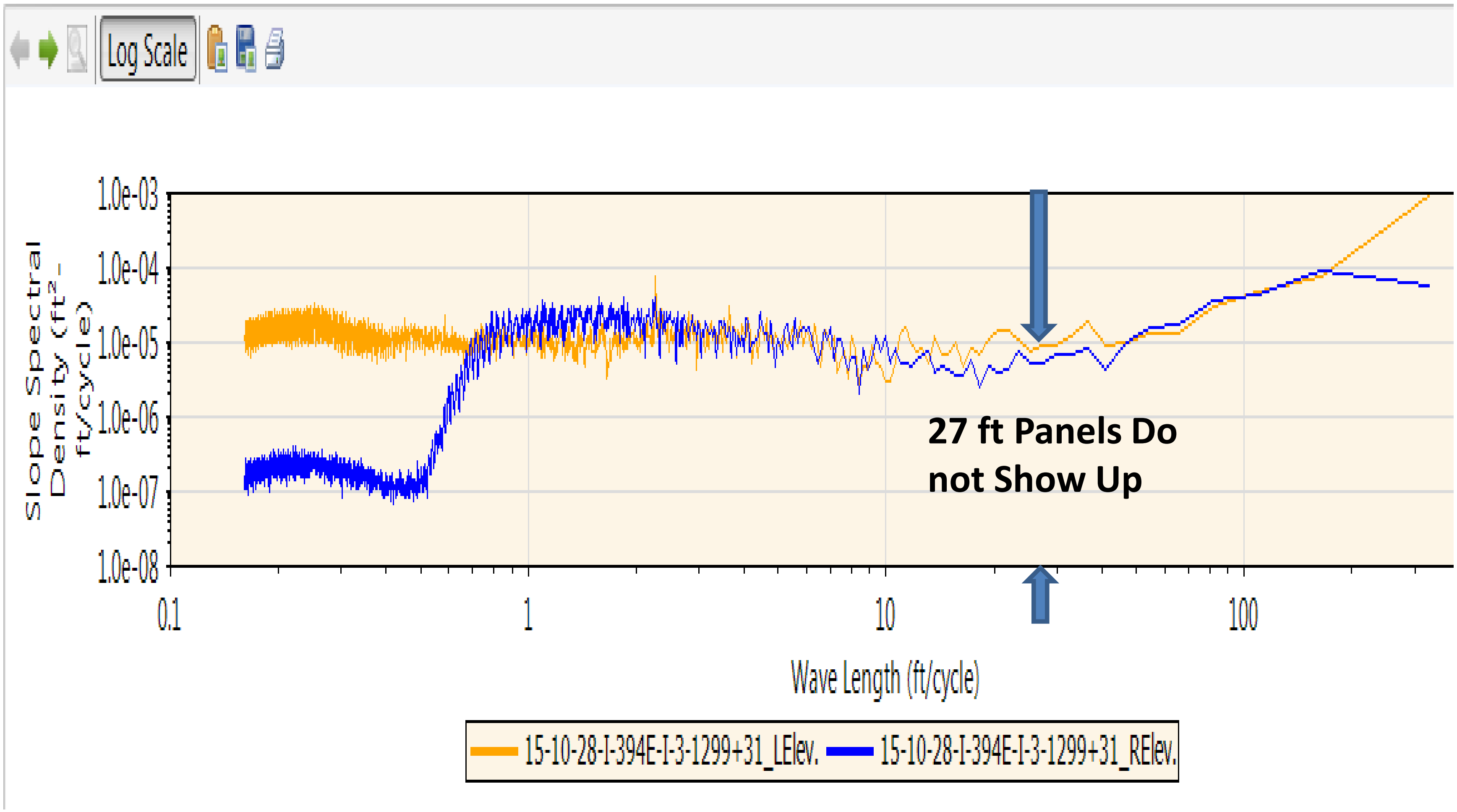


Core #2		a		b		c		d
		12.80		4.40		16.70		5.00
		12.80		4.50		17.60		5.50
		12.70		4.60		17.50		5.00
		13.20		4.50		17.60		5.10
		12.40		4.50		17.60		5.50
	Mean	12.78		4.50		17.40		5.22

RIDE PERFORMANCE



JOINT, WARP N CURL EFFECTS REDUCED BY GRINDING



CONCLUSION

- **NGCS at MnROAD 98 dB in the MnROAD test cells (Izevbekhai & Wilde 2011).**
- **Significant Ride improvement**
- **I-394 NGCS OBSI (101 to 103 dBA) was not as quiet as typical NGCS.**
- **Grooves in the NGCS Depth >> 3 mm of typical NGCS design. Groove depths in some sections in this project were as high as 5 mm.**
- **Excessive Groove Depth but Still Much Quieter than UTBWC**
- **MnDOT’s Metro District Met Stated Goal**

ACKNOWLEDGEMENTS

- This Research was Sponsored by a **Huge** Federal Grant in the amount of ……..
- $0.00
- Chris Kufner, Glenn Engstrom and Dave Van Deusen Approved My Time Sheet.
- Co-Authors: Eddie Johnson & Steve Olson
- Curtis Turgeon, Maria Masten & Gordon Bruhn
- Metro: Vanaki Nariman, Ron Rauchle, Peter Wasko Chris Kufner, Tim Clyne , Jon Erickson

QUESTIONS